Technology DNA of MMC

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Abstract

The technology DNA of Mitsubishi Motors Corporation (MMC) is based on MMC's excellence in three areas: engine technologies, which we originally learned from the demanding field of aircraft development; vehicle-dynamics technologies, which we refine through participation in rallies under severe driving conditions; and packaging technologies, through which we offer customers new lifestyle possibilities and added value. MMC must continue to make advances in all these areas as it builds a strong brand identity.

Key words: *DNA, Engine, Vehicle-Dynamics, Packaging, Brand*

1. Introduction

MMC's history of vehicle development began in 1917 with the Mitsubishi Model-A, Japan's first mass-production passenger car (**Fig. 1**)(1). Twenty-two units of the Mitsubishi Model-A were made through 1921 – a period in which there were very few cars in Japan. (The only other cars in Japan were imported from Europe and the United States.) Mitsubishi established itself as Japan's pioneering automaker, going on to develop models such as the Mitsubishi PX-33 in 1937, which was Japan's first full-time four-wheel-drive (4WD) vehicle.

From its earliest days, the Mitsubishi automaking operation has had a close relationship with the aircraft-development division of Mitsubishi Heavy Industries; many aircraft-related technologies have been put to effective use in Mitsubishi vehicle development. Since any technological problem in an aircraft directly impacts the lives of occupants, the level of technological excellence demanded of aircraft is far higher than that demanded of vehicles. For example, an engine fault can prevent an aircraft from staying in the air; poor fuel efficiency can limit an aircraft's flying range, rendering the aircraft unable to return to base; and in the case of a fighter aircraft, poor power performance can limit speed and altitude, putting the aircraft in danger of being shot down. In other words, aircraft need superior durability, reliability, fuel efficiency, and power performance. MMC has applied the same uncompromised standards to engine development for vehicles. The benefits have been reflected in numerous industry-leading technologies such as the MCA-JET system(2) (a unique lean-combustion technology that realized superior fuel efficiency plus early compliance with Japan's 1978 exhaust-emission regulations – the world's most stringent exhaust-emission regulations at the time); performance-enhancing turbocharging technologies and valve timing control technologies (including the MIVEC engine); and the GDI engine (a gasoline direct-injection system enabling incomparably low fuel consumption).

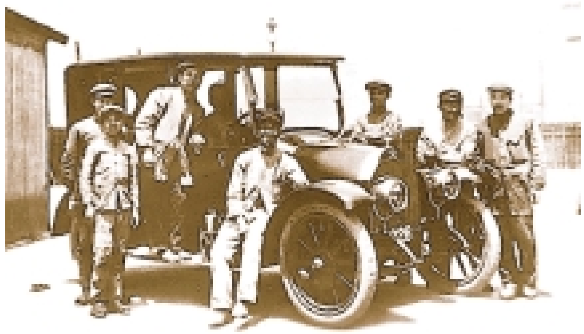

Fig. 1 Mitsubishi Model-A

These technologies are behind MMC's reputation for excellence in the field of engines.

Aircraft technologies have also been put to good use in areas of Mitsubishi vehicle development other than engines. Notably, the Mitsubishi 500 (**Fig. 2**), which went on sale in 1960, had superior aerodynamic performance because it was the first Japanese vehicle to be developed with the aid of wind-tunnel tests. In 1962, the Mitsubishi 500 was the first Japanese car ever to race in the Macao Grand Prix, where it took first, second, and third places in Class A (up to 750 cc). This race victory marked the start of a glorious Mitsubishi motorsports heritage. MMC won the 7th Southern Cross Rally in 1972 and went on to win the Southern Cross Rally in each of the four following years. And since then, other MMC vehicles including the LANCER EVOLUTION and PAJERO have demonstrated MMC's technological excellence through victories in the FIA World Rally Championship, Dakar Rally (**Fig. 3**), and other rally competitions around the world. Competing in the severe driving conditions imposed by rally competitions has, over the years, enabled MMC to refine the vehicle-dynamics technologies that form part of its technology DNA.

Further, MMC has proved itself a concept leader by continuously anticipating the needs of motorists and

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Fig. 2 Mitsubishi 500

Fig. 3 MMC's victory in the 2005 Dakar Rally

developing new kinds of vehicles suited to contemporary lifestyles. MMC's leadership in this area is exemplified by the first-generation MIRAGE, in which MMC was an early adopter of the front-engine front-wheel-drive (FF) configuration on which most compact cars are now based, by the RVR and SPACE GEAR, through which MMC offered consumers new ways to spend their growing leisure time, and by the PAJERO, a full-fledged Sports Utility Vehicle (SUV) that makes off-road driving easy and enjoyable. The packaging technologies behind these industry-leading offerings form, like MMC's engine technologies and vehicle-dynamics technologies, a core element of MMC's technology DNA.

Expectations for MMC's future engine, vehicle-dynamics, and packaging technologies are discussed hereafter.

2. MMC engine technologies

The role of an engine is to efficiently convert the chemical energy of fuel into kinetic energy. Efficient conversion of fuel's chemical energy into kinetic energy is dependent on how well a large amount of fuel can be introduced in a unit period of time and used to produce power (for high output) and on how well the introduced fuel can be converted into energy (for high fuel efficiency). Other demands include low weight (essential for high dynamic performance); low vibration and noise (essential for comfort); and low emissions, high durability, high reliability, low cost, low energy consumption during production and operation, and high recyclability (all essential for social acceptability).

Particularly since the 1992 United Nations Conference on Environment and Development, growing environmental concern has prompted diversification of vehicle powertrains. Vehicles available now include not only internal-combustion-engine vehicles but also hybrid vehicles, and in smaller numbers, electric vehicles and fuel-cell vehicles. Nevertheless, internal-combustion-engine vehicles remain dominant, with the market divided between those with gasoline engines and those with diesel engines. In Japan and the United States, gasoline engines are more prevalent owing partly to their compactness and lightness and partly to the relative ease with which they can be made to deliver high power with low emissions. In Europe, by contrast, diesel-engine vehicles have, owing to their economical operation, become popular to the extent that they account for about half of newly registered passenger vehicles.

It is difficult to predict what form of vehicle powertrain will be most prevalent in the future. But in light of ongoing armed conflict and political instability in the Middle East, increasing crude-oil prices that are accompanying rapid growth of energy consumption in developing countries, and ongoing tightening of fuel-consumption regulations in industrialized countries, any attempt at prediction must conclude at least that thermal efficiency will be increasingly crucial.

Gasoline engines are characterized by high power density but suffer relatively low thermal efficiency when partially loaded, so efforts to improve efficiency in gasoline engines have thus far focused on increasing partial-load thermal efficiency while maintaining or increasing power density. MMC took a major step forward in 1996 with the development of the GDI engine, the world's first volume-produced lean-burn direct injection gasoline engine (**Fig. 4**). MMC's GDI technology was hailed inside and outside Japan as the ultimate means of overcoming the inherent shortcomings of gasoline engines. The higher thermal efficiency yielded by GDI technology prompted some observers to comment that there was no longer any need for passenger-car diesel engines; it triggered the subsequent advance from indirect-injection diesel engines (the type of engine that had been prevalent in diesel passenger cars) to direct-injection diesel engines. Diesel engines have since shown great advances in power, thermal efficiency, and emissions performance owing to high-pressure direct injection (made possible by electronically controlled common-rail fuel-injection technology) and to high boost pressure (made possible by advanced turbochargers). In fact, the most important advantage of gasoline engines, namely the ease with which load control can be effected using throttle valves, has come to be seen as less of an advantage since the pumping losses caused by throttle valves are hindering improvements in gasoline engines' thermal efficiency. To remedy this situation, it is urgently important to eliminate the factor that is hindering improvements in gasoline engines' thermal efficiency. In other words, gasoline-engine developers are likely to pursue higher thermal efficien-

Fig. 4 GDI engine

Fig. 5 New-generation engine

cy using throttle-valve-less designs while seeking further improvements in gasoline engines' inherently high power density.

With diesel engines, low power density, which has been seen as a major inherent weakness, has been overcome by direct fuel injection and turbocharging. And other shortcomings of diesel engines, namely their high vibration and noise and the difficulty of suppressing their nitrogen-oxide and particulate-matter emissions, have been resolved in large part by common-rail fuel-injection technology. As direct-injection technology becomes more advanced, concomitant improvements in fuel efficiency will likely drive further improvements in emissions performance.

As internal-combustion engines become more advanced and efficient, further increases in overall efficiency can be expected as internal-combustion engines are combined with continuously variable transmissions (CVT), automated manual transmissions, and other new power-transmission systems.

Hybrid vehicles, which combine internal-combustion engines with electric motors for superior overall efficiency, are attracting attention. However, hybrid systems are complex and are heavier and more costly than internal-combustion engines, so it is unlikely that hybrid vehicles will completely displace internal-combustion-engine vehicles. It is more likely that gasoline engines, diesel engines, and hybrid systems will co-exist as their respective technologies continue to evolve.

Beginning with the new COLT, which went on sale in Europe in April 2004, MMC has been introducing new-generation engines (**Fig. 5**) across its entire vehicle range to replace existing three-cylinder mini engines, four-cylinder small and compact engines, and six-cylinder gasoline engines. The most important features of each of the new-series engines are an aluminum cylinder block and a MIVEC valve timing control system. The lightness of the cylinder block promotes the fundamental running, turning, and stopping aspects of dynamic performance. At the same time, the MIVEC system controls the volume and flow pattern of air drawn into each cylinder. The controlled intake flow optimizes combustion such that high efficiency and high power are simultaneously realized throughout the rev range and such that emissions can potentially be kept within the limits imposed by increasingly stringent regulations. In addition to these structural merits, MMC's new-series engines reflect comprehensive efforts to minimize frictional losses, maximize rigidity, and optimize clearances between sliding parts. The resulting benefits in high power, low fuel consumption, and low noise and vibration translate into performance befitting next-generation gasoline engines.

With its new-generation gasoline engines forming the core of its efforts, MMC will, notwithstanding powertrain leadership challenges posed by diesel engines and hybrid systems, continue to refine and advance the engine technologies that form a key part of MMC's technology DNA, thereby retaining its competitive edge.

3. MMC vehicle-dynamics technologies

High dynamic performance can be defined as the ability of a vehicle to behave safely and precisely in accordance with the driver's wishes in diverse operating environments. More specifically, it can be defined as the ability of a vehicle to continuously remain stable while making maximal use of the force that acts between the tires and the road surface.

Dynamic performance defined in these terms was originally refined through improvements in vehicles' basic specifications and suspension mechanisms, but since the mid-1980s chassis-control technologies such as electronically controlled suspension (ECS) systems and four-wheel steering (4WS) systems have realized more marked improvements.

MMC is a pioneer in this field. In addition to making advances in four-wheel independent suspension and other fundamental chassis technologies, MMC developed the world's first active ECS system (a means of actively controlling a vehicle's cornering attitude and dynamic performance) and adopted it in the 1987 GALANT. MMC's active ECS system not only enhanced ride comfort; it also kept body inclination to a minimum under all driving conditions and thus optimally controlled the grip between the tires and the road surface. The 1987 GALANT also incorporated a 4WS system that caused the rear wheels to exert lateral force sooner than with conventional steering, resulting in markedly improved yaw-direction stability at high vehicle speeds. These MMC technologies realized high dynamic performance in driving environments where it could not be realized with earlier technologies. In this sense, they greatly changed the concept of driving safety.

Development of electronic control technologies for suspension and steering subsequently slowed. From the mid-1990s, developers turned their attention mainly to high-cost-performance forms of braking control. MMC led the industry with the development of technologies that enabled a vehicle's yaw motion to be con-

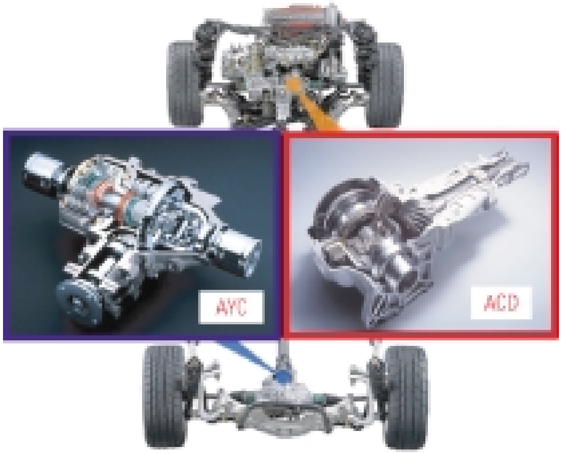

Fig. 6 AYC system

trolled by means of powertrain components, and in 1996 MMC incorporated these technologies in the GALANT and LANCER EVOLUTION in the form of the world's first active yaw control (AYC) system (**Fig. 6**), which promoted and controlled the vehicle's yaw moment as necessary by optimally controlling the torque difference between the left and right rear wheels. More recently, attention has been focused on stabilizer-control technologies that provide the roll stiffness that is required during cornering maneuvers. With SUVs and other vehicles with high centers of gravity, such technologies are effective both at preventing excessive roll movements and at enhancing rough-road drivability. MMC has proven its value in the PAJERO in the Dakar Rally.

In the years ahead, further advances in torque-control technologies, further advances in electronically controlled braking systems (namely active stability control systems and anti-lock braking systems), further advances in electronically controlled steering systems, and new combinations of these technologies can be expected to yield even more sophisticated and effective means of controlling vehicles' dynamic performance.

Recent demands for increased cabin space have caused vehicles to be made with greater overall lengths and heights, with the result that vehicle inertia moments are also tending to increase. This trend is disadvantageous from the point of view of dynamic performance. An effective countermeasure is to make components that are far from a vehicle's center of gravity as light as possible, thereby effectively lowering the center of gravity. MMC's success in this regard is exemplified by the LANCER EVOLUTION MR, in which MMC used aluminum not only for the hood but also for the roof, thereby achieving a low inertia moment and concomitantly high dynamic performance. A further benefit of such weight-saving techniques is significantly improved fuel economy.

Vehicle-dynamics technologies also aim more safety driving. Although passive-safety technologies realize significant reductions in fatalities caused by traffic accidents, active-safety technologies, which are intend-

Fig. 7 PAJERO

ed to enable drivers to avoid collisions, are attracting worldwide attention. Vehicle-dynamics technologies are inextricably linked with active safety. In Europe, a Primary New Car Assessment Programme (a programme intended to enable independent assessment of active-safety performance in parallel with the European New Car Assessment Programme that already enables independent assessment of passive-safety performance) has recently been proposed and will likely be a major factor driving further advances in vehicle-dynamics technologies.

For MMC's vehicle-dynamics superiority to grow into part of a strong brand identity, it is vital for MMC to feed back into its volume-production vehicles the technologies through which it pursues uncompromised driving safety in its rally vehicles. While pursuing improvements in dynamic performance through improvements in terms of lightness, suspension characteristics, body stiffness, and other fundamental attributes of its vehicles, MMC will continue to pursue superior vehicle dynamics through complementary advances in electronic control technologies.

4. MMC packaging technologies

Packaging defines the interface between a vehicle and the people who use it; it embodies the concept behind the vehicle. Particularly since the 1990s (the period following the bursting of Japan's economic bubble), consumers' priorities have diversified, making packaging an increasingly crucial element in the consumer appeal of any vehicle. MMC is a leader in this regard, having continually led the industry in the introduction of new forms of vehicles taking advantage of new technologies.

With the first-generation MIRAGE, which went on the market in 1978, MMC established the precedent of using the FF configuration for compact cars. This vehicle not embodied the benefits of FF technologies in terms of increased cabin space and lower weight; it was also distinguished by flush surfaces, which improved aerodynamic performance and limited wind noise.

In 1982, the PAJERO (**Fig. 7**) changed the face of off-road vehicles. Until then, off-road driving could be enjoyed by just a small proportion of motorists using Jeeps and other military-style vehicles. With the PAJERO, MMC added comfort to off-road capability, making off-road driving enjoyable for the wider motoring public. Superior visibility provided by a high eye point also contributed to the PAJERO's popularity. The

Fig. 8 DELICA 4WD

PAJERO was the spark for the subsequent SUV boom. Also in 1982, MMC launched the DELICA 4WD (**Fig. 8**), in which it added a high-level of off-road capability to a one-box-type vehicle (a kind of vehicle previously seen as limited to commercial use), thereby offering families the new lifestyle option of taking camping gear out to the countryside and mountains to enjoy the great outdoors together. The DELICA 4WD proved popular with many customers. In 1983, MMC developed the CHARIOT, an FF passenger car in which three seating rows enabled a whole family to ride in comfort. The CHARIOT was distinguished also by a high eye point and a concomitantly wide field of driver visibility, which promoted safety. It was instrumental in creating the minivan market segment, which has since become huge. In 1990, MMC launched the convenience-oriented MINICA TOPPO, which offered the easy drivability of a bonnet-type vehicle with the tall cabin of a one-box-type vehicle, and the DIAMANTE, which created a market segment for medium-sized sedans. Then in 1991, MMC launched the RVR, a highly acclaimed model in which a fully flat floor and long-slide seats were combined with neat styling that was made possible by an inner-rail-type sliding door – a further demonstration of MMC's position as a concept leader that continuously anticipates the needs of motorists and responds with new kinds of vehicles for new lifestyle possibilities.

Today, the car market is broadly divided into sedan, minivan, and SUV categories. Packaging technologies can be expected to continue evolving in each of these categories, and it is likely that packaging proposals for crossover cars that do not fit into any single category will continue to emerge. Packaging engineers must continue striving to create new ways to maximize cabin roominess within limited dimensions while also enabling the incorporation of various powertrains and measures for compliance with increasingly stringent collision-safety regulations. Many technological challenges – these include finding ways to realize pillarless doors (for easier cabin ingress and egress and a stronger sense of openness), diverse seat arrangements that can be selected with a single touch, low floors, and low centers of gravity – remain to be overcome. At the 2003 Tokyo Motor Show, MMC demonstrated its intention to continue addressing these challenges by unveiling the "i" (**Fig. 9**), a new-platform minicar combining outstanding styling with interior spaciousness comparable with that of larger vehicles. With the sportiness and SUV attributes of MMC product DNA at the core of its efforts, MMC will continue to develop packaging for vehicles with new forms of added value in every segment of the market.

Fig. 9 "i"

5. Conclusion

An automobile is a combination of technologies from wide-ranging fields including mechanics, electrics and electronics, and chemistry, and each automaker attempts to differentiate itself from others by building a brand identity using technologies in which it has particular strength. MMC, for its part, will continue to relentlessly make advances in the three areas (engine technologies, vehicle-dynamics technologies, and packaging technologies) that form the basis of its technology DNA, thereby enabling itself to continue building a strong brand identity and to continue developing and offering vehicles that delight customers.

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